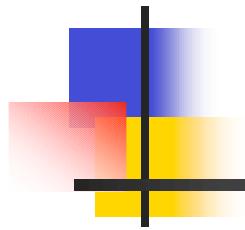
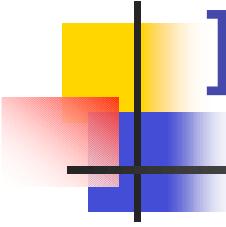


# LQ search in $e\bar{e}jj$ channel



Simona Rolli ( TUFTS)

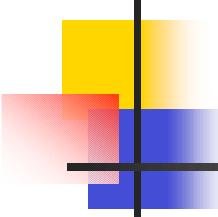
-Blessing-



# Introduction

---

- This analysis is an update of the result produced in June 2003
- REMAKE data 4.11.1 up to Summer shutdown used - 203 pb<sup>-1</sup>
- New treatment of efficiencies
  - ID efficiencies used in MC and scaled to data
- New good run list
- Revised final selection cut
  - New MET cut raised at 60 GeV
  - New cut around the nominal LQ mass



# Issues from pre-blessing

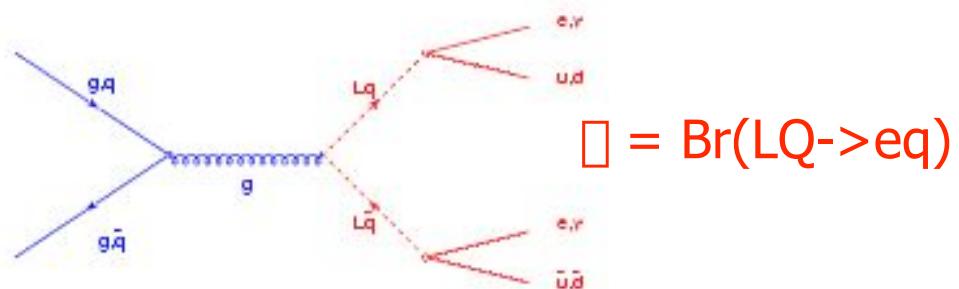
---

- More Plots
- Mass cut - checking alternative combinations
- QCD background
- Systematics ( pdf)

# LQ production at the TeVatron

## ■ Production

- $qg \rightarrow LQ + L\bar{Q}$
- $gg \rightarrow LQ + L\bar{Q}$
- $q\bar{q} \rightarrow LQ + L\bar{Q}$



## □ Decay

- $LQLQ \rightarrow l^+l^-qq, l^\pm\bar{q}q, \bar{q}\bar{q}qq$

## □ Experimental signature:

- High pt isolated leptons (and/or MET) + jets

In this analysis:  $e \pm + 2 \text{ jets}$

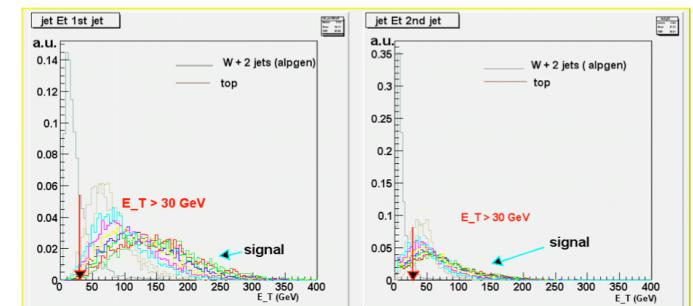
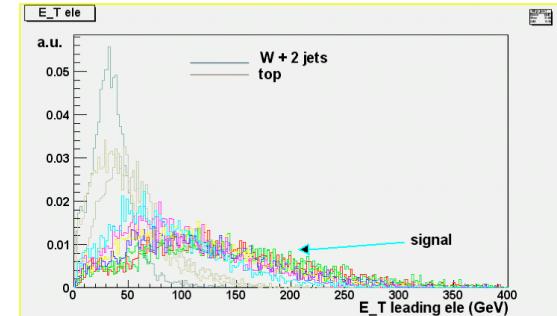
$M_{LQ} (\text{GeV}/c^2)$	$\text{Br}(\text{NLO}) [\text{pb}]$
200	0.265E+00
220	0.139E+00
240	0.749E-01
260	0.412E-01
280	0.229E-01
300	0.129E-01
320	0.727E-02

# LQ search in $e\Box jj$

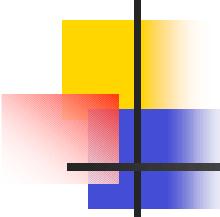
Signature: 1 electron, 2 jets and large MET

## Analysis cuts

- 1 central electrons with  $E_T > 25$  GeV
- MET  $> 60$  GeV
- Veto on 2nd electron, central loose or Plug
- 2 jets with  $E_T > 30$  GeV
- $\Delta\phi$  (MET-jet)  $> 10^\circ$
- $E_T(j1) + E_T(j2) > 80$  GeV
- $M_T(e-\Box) > 120$
- LQ mass combinations



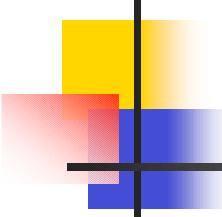
Events with 2 central/plug electrons are rejected  
(to be orthogonal to eejj analysis)



# Tools

---

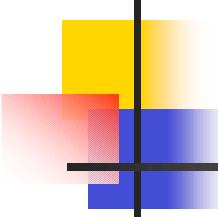
- Signal generated and reprocessed with 4.9.1
  - 5000 events at masses from 100 to 280
    - run number 151435
    - full beam position
      - talk GenPrimVert
      - BeamlineFromDB set false
      - sigma\_x set 0.0025
      - sigma\_y set 0.0025
      - sigma\_z set 28.0
      - pv\_central\_x set -0.064
      - pv\_central\_y set 0.310
      - pv\_central\_z set 2.5
      - pv\_slope\_dx dz set -0.00021
      - pv\_slope\_dy dz set 0.00031
      - exit
- eN ( 4.9.1)used for ntuple analysis
  - <http://ncdf70.fnal.gov:8001/talks/eN/eN.html>



# Efficiencies & acceptance

$$\square_{\text{tot}} = \square_{\text{Acc}}(M) \times \square_{\text{ID}}^{\text{data}} / \square_{\text{ID}}^{\text{MC}} \times \square_{z_0} \times \square_{\text{trig}}$$

- Trigger
  - Top/EW - we use  $0.961 \pm 0.005$
- Efficiencies for electron selection cuts
  - Z' analysis : one tight electron  
 $\square_t = 94.5 \pm 0.2 \%$
- Other
  - eff. on the vertex cut ( $|z_0| < 60 \text{ cm}$ )  $95.2 \pm 0.1 \text{ (stat)} \pm 0.5 \text{ (sys)}$



# Kinematical and geometrical acceptance

- Events are selected where the electron satisfies the tight requirements of the exotic group. The analysis (kinematical) cuts are then applied.

## Central electron tight

- $E_t \geq 25 \text{ GeV}$
- $p_t > 15 \text{ GeV}$
- $\text{hadem} \leq 0.055 + 0.00045 * E$
- $E/p < 4$  (for  $E_T < 100 \text{ GeV}$ )
- $\text{iso4e}/\text{emet} < 0.1$
- $|\Delta x| < 3.0$
- $|\Delta z| < 5.0 \text{ cm}$
- Fiducial = 1
- $I_{\text{sh}} < 0.2$

HEPG electrons are then matched in a  $\Delta R = (\Delta\phi^2 + \Delta\eta^2)^{1/2}$  cone to the reconstructed electron :

ID efficiencies are calculated on them scale factor to data is derived:  $\epsilon^{\text{data}}/\epsilon^{\text{MC}}$  the events surviving the final kinematical cuts are normalized to the number of matching electrons;

# Mass Cut

The invariant mass of the electron-jet system and the transverse mass of the neutrino-jet system are selected where the jet assignment is made such that the difference between the electron-jet mass and the neutrino-jet transverse mass is minimized.

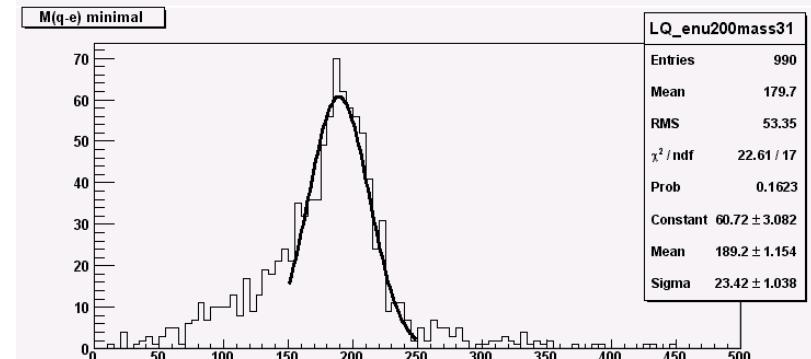
The peak of the  $ej$  histogram is fitted with a gaussian

rough estimate of the spread of the distribution in the signal region.

Several masses ( 120-160-200-240-280) tested:

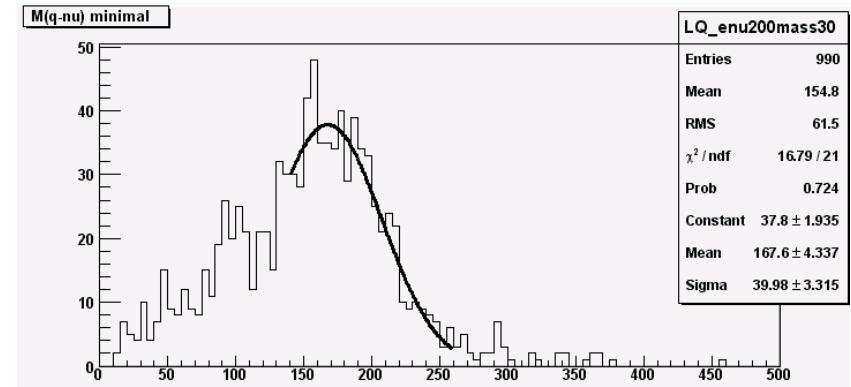
$$\Delta_e \sim 15\%.$$

$3\Delta_e$  cut around the nominal mass to select LQ candidates of a given mass.



# Mass Cut ( continued)

The  $\square$ - $q$  transverse mass distribution is fitted including the high mass tail end, with a Gaussian to estimate the signal spread.  $\square \sim 25\%$ .

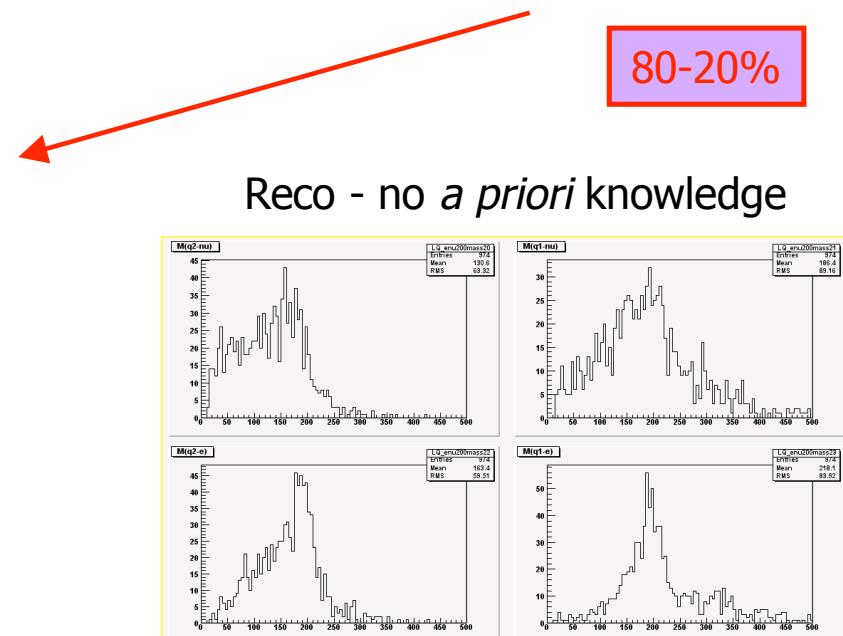
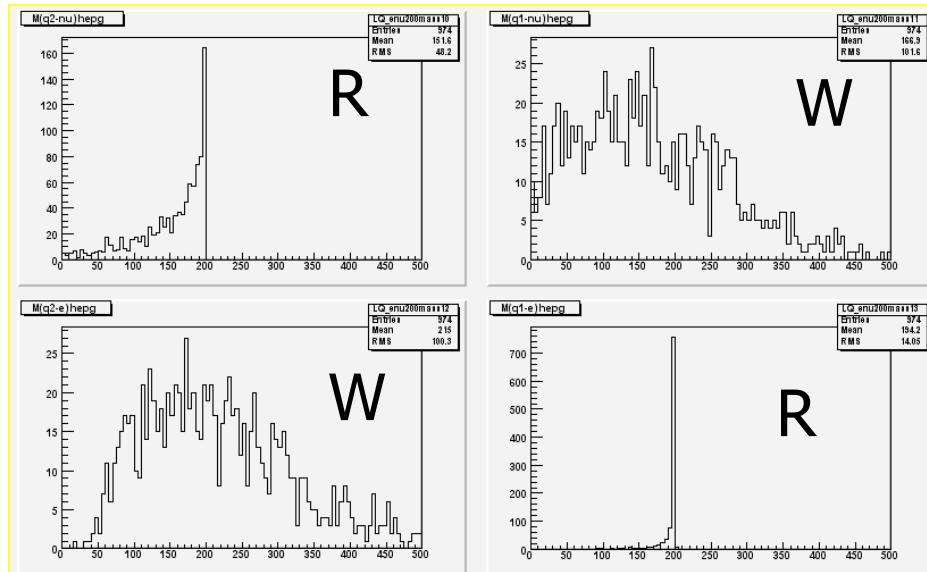


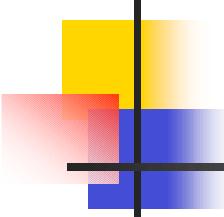
$3\square$  cut applied around the nominal mass

# Mass Cut issues

How many times the combination picked is the right one?  
Tested on several masses: 75%

Is this number too low? Transverse mass has a large tail already at HEPG level





# Mass cut issues

We tested other methods in order to evaluate S/B:

- 1) Both combinations (Cut2)
- 2) The combination where the objects are most back to back (Cut3)

LQ mass region	Cut1	Cut2	Cut3	W+2 jets Cut1	W+2 jets Cut2	W+2 jets Cut3	Top Cut1	Top Cut2	Top Cut3
$m(LQ) = 160$	11.7	13.5	9.7	2.5	2.5	4.0	2.6	3.8	1.8
$m(LQ) = 200$	4.46	5.2	3.9	2.5	3.0	4.0	1.8	3.4	1.2
$m(LQ) = 240$	1.6	1.9	1.5	2.0	2.5	3.0	1.0	2.8	0.5

# Mass cut issue ( cont'd)

S/B is best for the original choice ( also chosen in Run I)

We decide to keep using this mass window definition

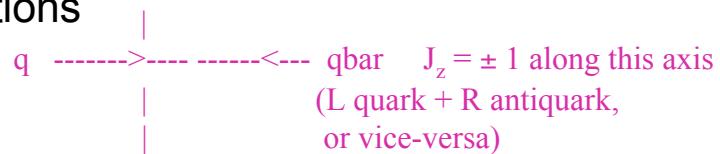
A comment on  $\square \square$  of decay products of LQ

(E.Perez):

One would naively expect that the  $\square \square$  distributions  
of the decay products of  
the LQ would be back to back.

In reality the  $\square \square$  distributions are quite  
distorted due to the large  $P_T$  boost the  
LQ gets. Indeed the LQs are produced  
with a significant  $P_T$ .

This is because they are *scalar* particles



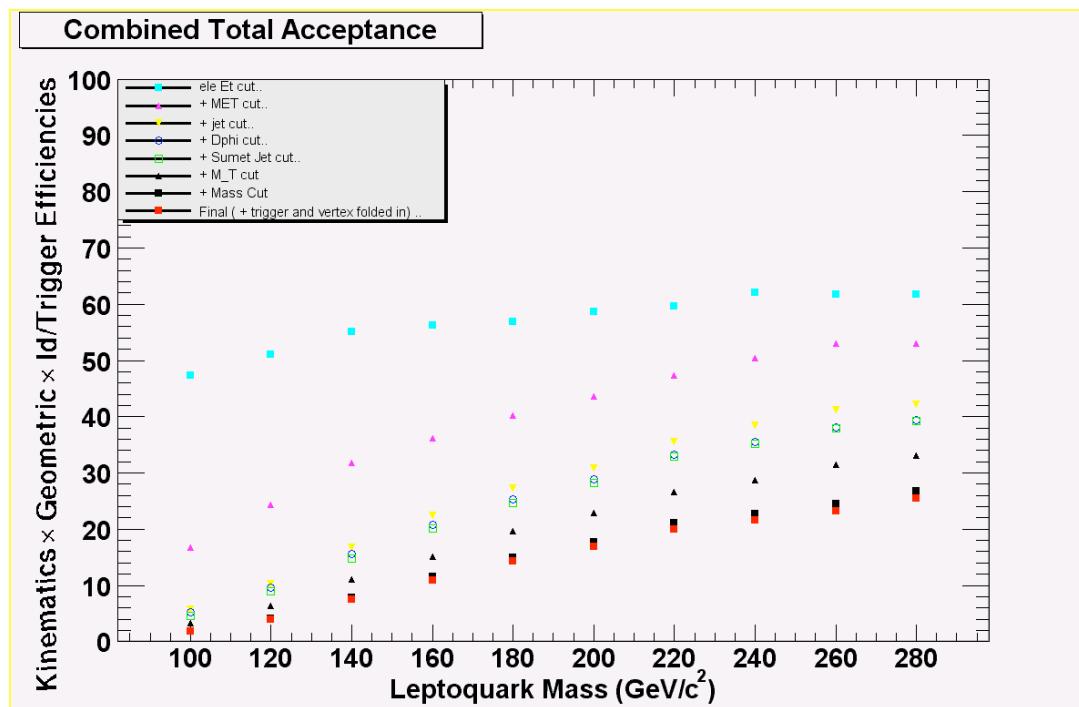
$J_z = 0$  in the final state since the LQs are both scalars.

Hence to conserve the  $J_z$  the preferred outgoing direction for the LQs  
(in the q-qbar c.o.m) is perpendicular to the q-qbar direction.  $\square^*$  peaks at  
90 degrees and the  $P_T$ 's of the LQs are quite large. (the exact pt distribution  
depending on the distribution of  $(s\hat{ })$ )

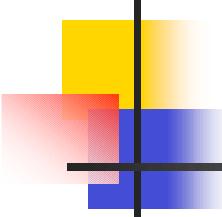
$t\bar{t}$  is not the same because of the 1/2 spin of the tops.

# Final Signal Expected

Number of expected events in  $203 \text{ pb}^{-1}$



Mass	Theory CTEQ4M (pb)		
	$Q^2 = M^2/4$	$Q^2 = M^2$	$Q^2 = 4M^2$
100	31	28	24.1
120	25	22.6	19.5
140	19.7	17.9	15.5
160	13.5	11.7	10.3
180	8.5	7.4	6.5
200	5.2	4.4	3.9
220	3.2	2.7	2.4
240	1.65	1.6	1.4
260	1.11	0.94	0.8
280	0.7	0.6	0.5



# Backgrounds

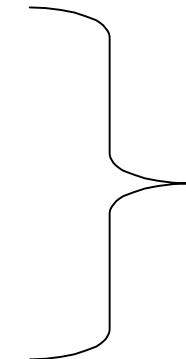
Main background sources:

$W + 2 \text{ jets}$

$Z + 2 \text{ jets w/ mismeasured electron}$

Top

$W(\square \square) + 2 \text{ jets} - \text{negligible}$



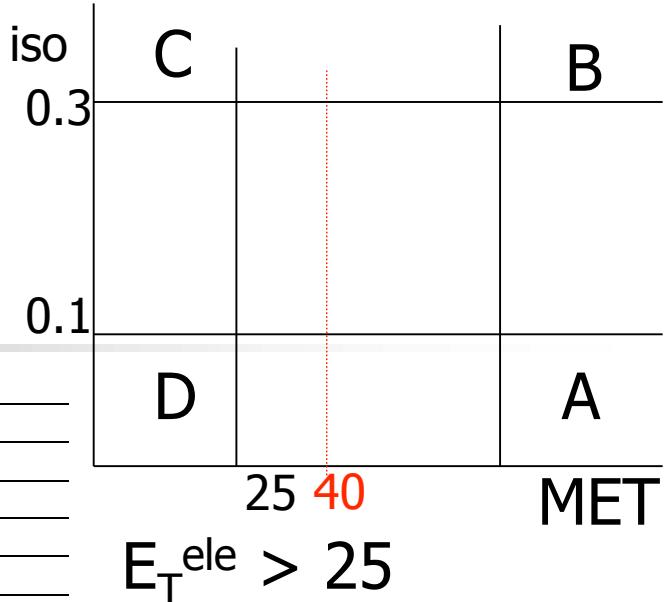
MC Alpgen  
Pythia

*atop02*  
*atop2e*  
*ttopei*

QCD fakes - from data iso vs MET negligible

# QCD background

Cut	A	B	C	D
lepton	1073	11	17863	71473
2 jets	125	2	578	1489
$\square\square$	104	2	474	1207
$M_T$	18	0	0	1



Cut	A	B	C	D
lepton	1252	11	32323	129500
2 jets	143	2	791	1761
$\square\square$	122	2	647	1444
$M_T$	18	0	0	1

$E_T^{\text{ele}} > 20$

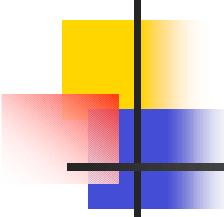
Cut	A	B	C	D
lepton	1073	11	18989	156995
2 jets	125	2	657	2191
$\square\square$	104	2	527	1757
$M_T$	18	0	1	42

$E_T^{\text{ele}} > 25$

$C) \text{MET} < 40 \text{ iso} > 0.3$

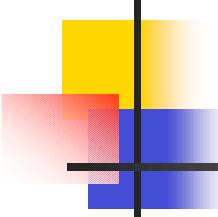
$D) \text{MET} < 40 \text{ iso} < 0.1$

Decided to consider it negligible



# Data sample

- btop0g (inclusive electrons) stripped from bhel08 and (4.8.4 Production)
- Inclusive-ele\_4.11.1\_REMAKE
- events selected from Ele\_18 && Ele\_70 triggers
- good runs from March 2002 to September 2003 (141544 - 168889)
  - Good run list from DQM page, em\_noSi version 4
    - Removed 4 runs due to CSL problem
    - Luminosity =  $199.7 * 1.019 = 203.5 \pm 12.2$
    - <http://www-cdf.fnal.gov/internal/dqm/goodrun/v4/goodyv4.html>



# W cross section

$\cancel{E}_T > 25 \text{ GeV}$

Relaxing the MET cut to 25 GeV we obtain 112384 candidate W events

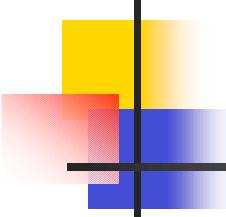
We use the same numbers used CDF6681 ( the background is scaled to the increased Luminosity) :

$$\sigma \cdot B(p\bar{p} \rightarrow W \rightarrow e\nu) = \frac{N_W - N_{BG}}{A_W \cdot \epsilon(Z_{vtx} < 60) \cdot \epsilon_c \cdot \epsilon_T \cdot R_{COT} \cdot R_{EMC} \cdot \int \mathcal{L} dt}$$

$$\begin{aligned} N_{BG} &= 1656 \pm 52(\text{stat}) \pm 295(\text{syst}) \\ A_W &= (23.895 \pm 0.03(\text{stat})^{+0.34}_{-0.39}(\text{syst}))\% \\ \epsilon(Z_{vtx} < 60) &= (95.0 \pm 0.2(\text{stat}) \pm 0.3(\text{syst}))\% \\ \epsilon_c &= (81.8 \pm 0.8(\text{stat}) \pm 0.2(\text{syst}))\% \\ \epsilon_T &= (96.6 \pm 0.1(\text{stat}))\% \\ R_{COT} &= (100.0 \pm 0.4)\% \\ R_{EMC} &= (99.8 \pm 0.4)\% \end{aligned}$$

$$\begin{aligned} N_W &= 112384 \\ N_{BG} &= 1656 * 203/72 \\ \int \mathcal{L} dt &= 203 \end{aligned}$$

$$\boxed{\sigma = 2.953 \pm 0.032_{\text{stat}} \pm 0.051_{\text{sys}} \pm 0.177_{\text{lumi}} \text{ nb}}$$



## W cross section ( cont'd)

We checked that we would get the same acceptance using W MC:  
wewk9e ( official EW group)

$$\text{Acc} = 0.213592 \pm 0.0013 \quad \square \quad 94.5/89.8 = 22.4 \pm 0.002$$

Our electron cuts are different: E/P in particular is relaxed  
Running w/ E/P tightened gives 107385 evts observed



$$\square = 2.816 \pm 0.031_{\text{stat}} \pm 0.049_{\text{sys}} \pm 0.168_{\text{lumi}} \text{ nb}$$

# W + 2 jets cross check

$\cancel{E}_T > 35 \text{ GeV}$

We checked the number of events we would expect after the 2 jets cut:

QCD background ( corrected for sideband contributions)  $38.5 \pm 6$

Top contribution  $56 \pm 8$

Z + 2 jets contribution  $\sim 25 \pm 3$

W $\rightarrow$  l $\bar{l}$  contribution  $16.6 \pm 2.6$

$136.5 \pm 20.4$

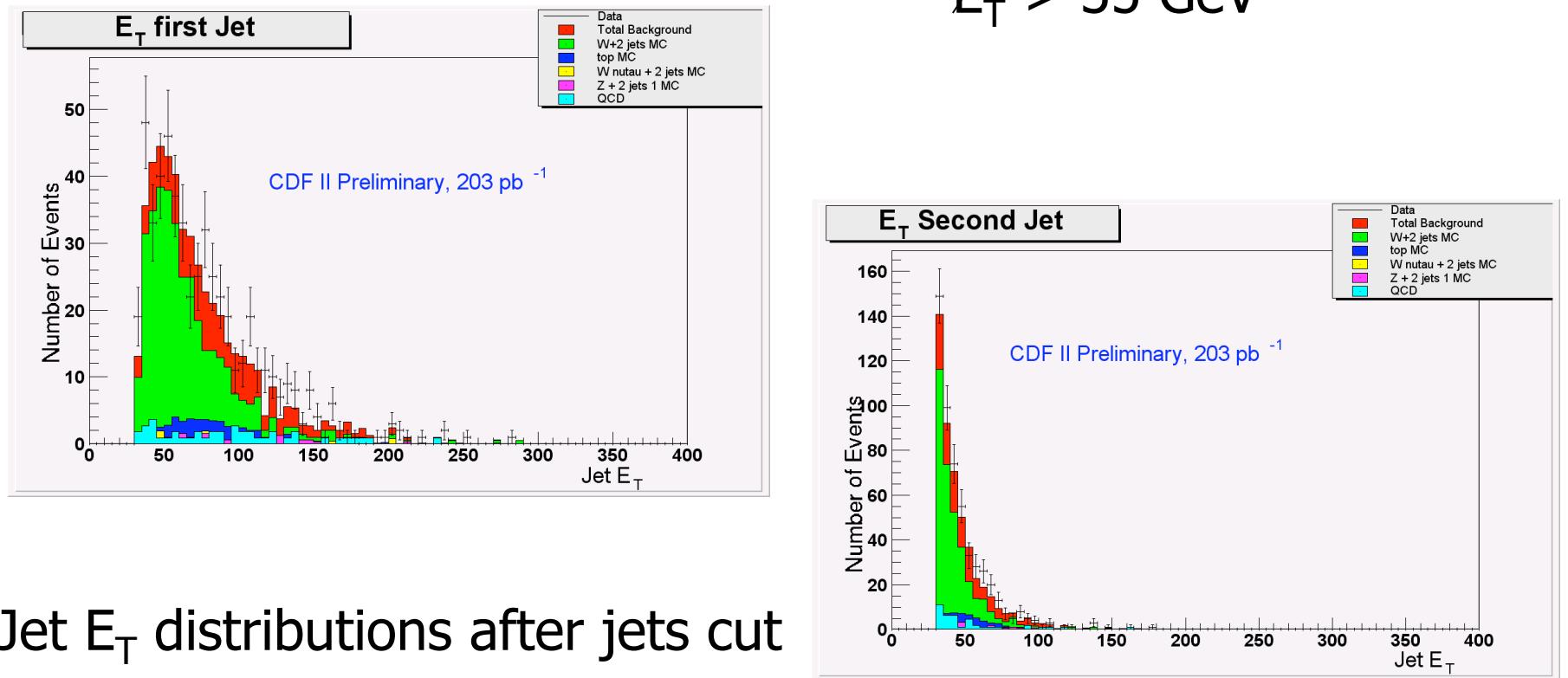
The number of expected W + 2 jets is

$366 \pm 17$

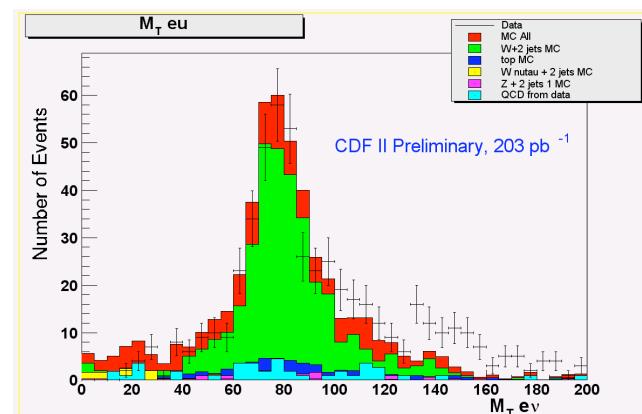
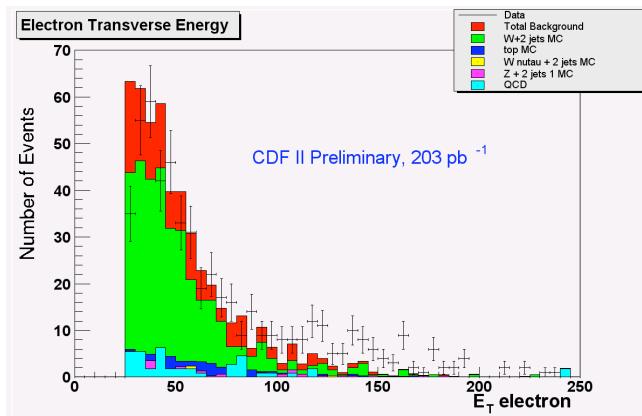
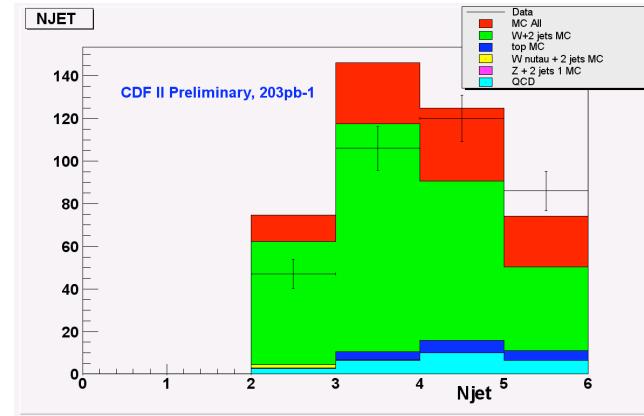
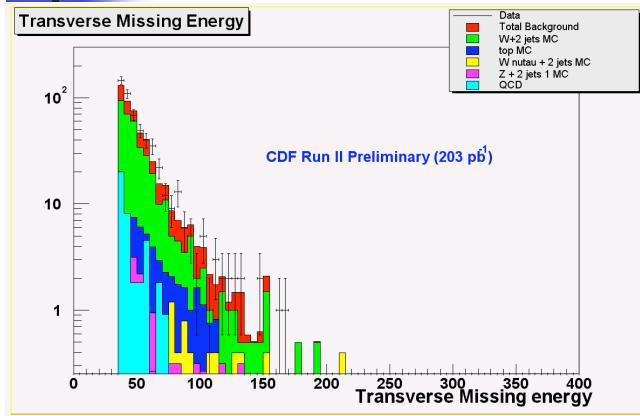
$\sim 503$

We observe 536 events

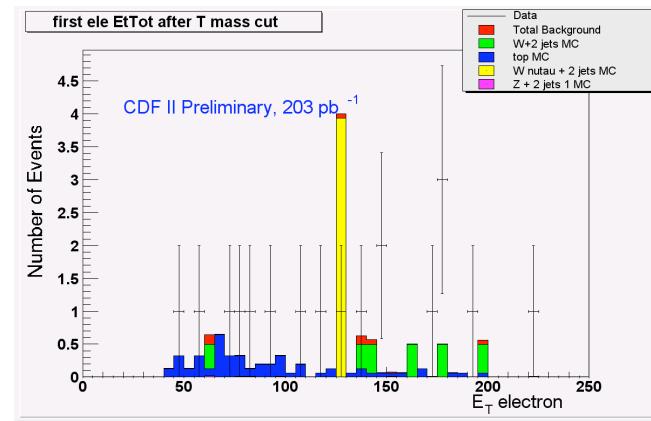
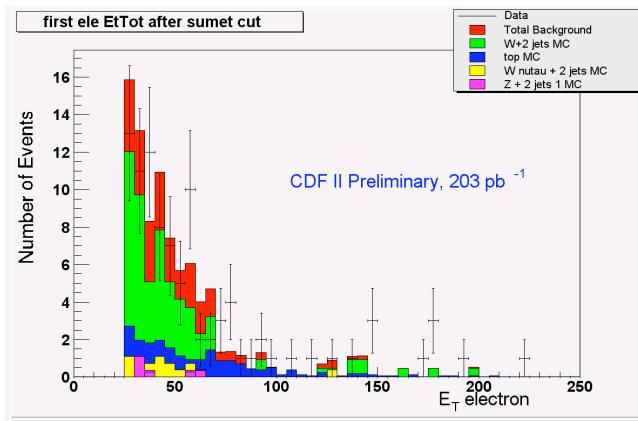
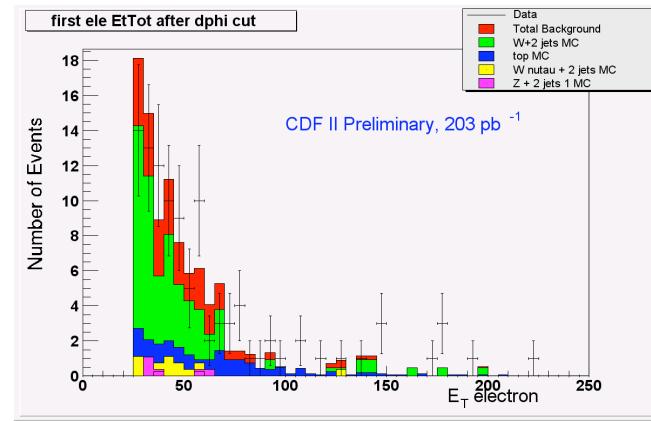
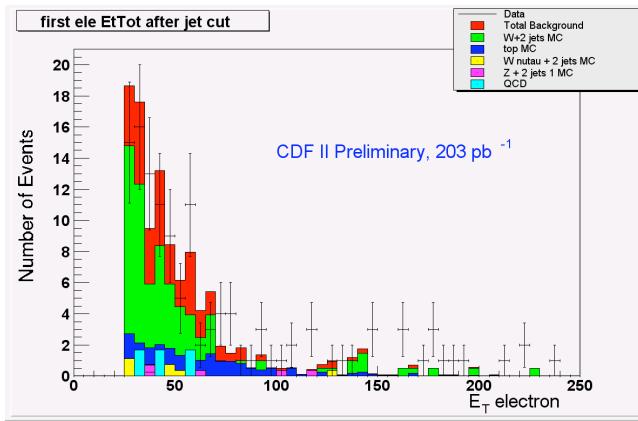
# W + 2 jets cross check



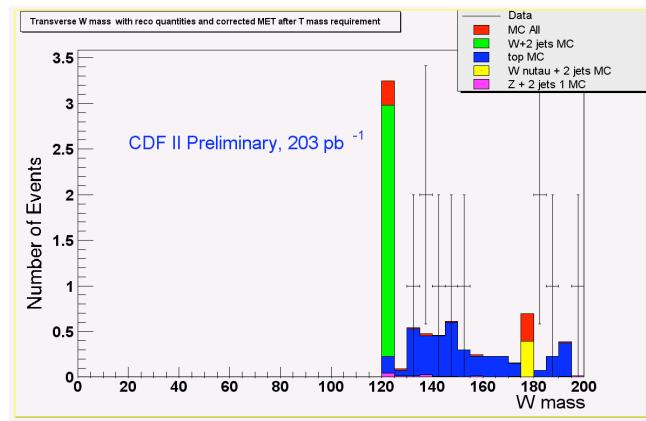
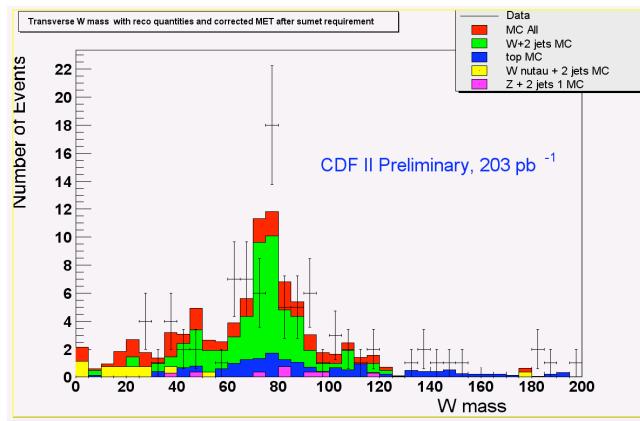
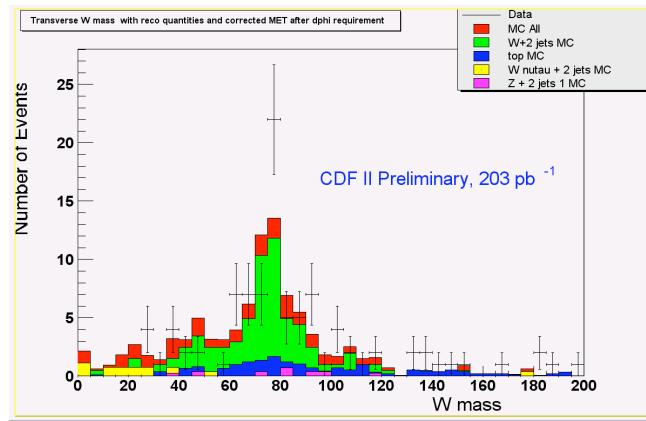
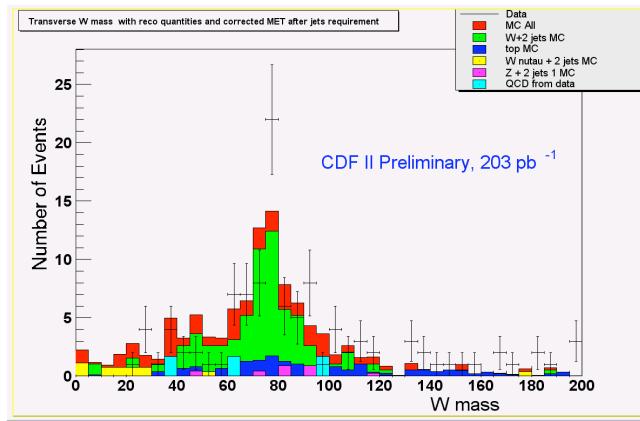
# W + 2 jets cross check



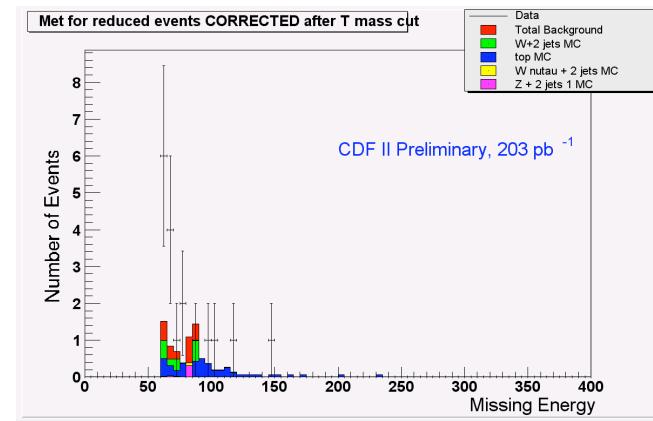
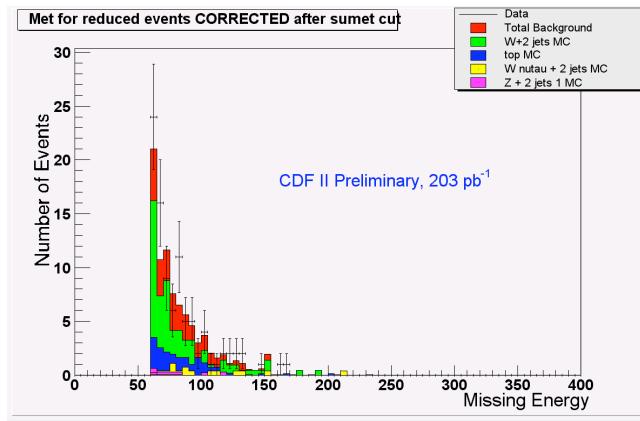
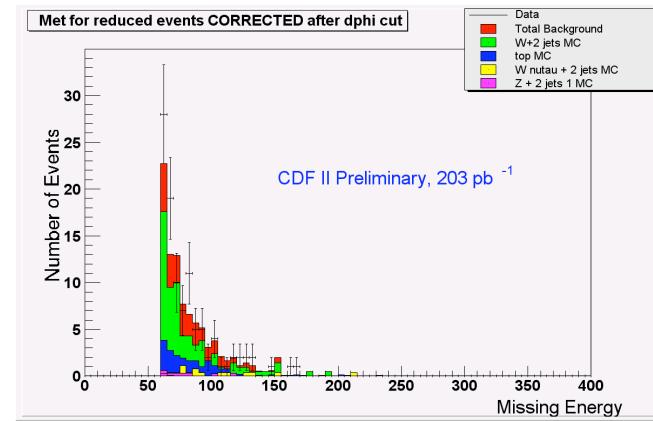
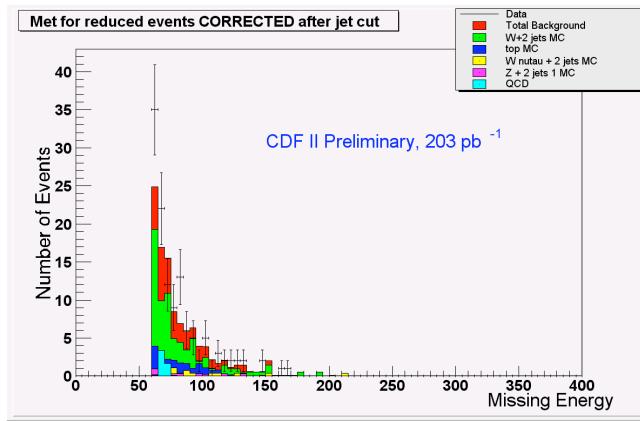
# Plots- Met > 60



# Plots - MET > 60



# Plots MET > 60

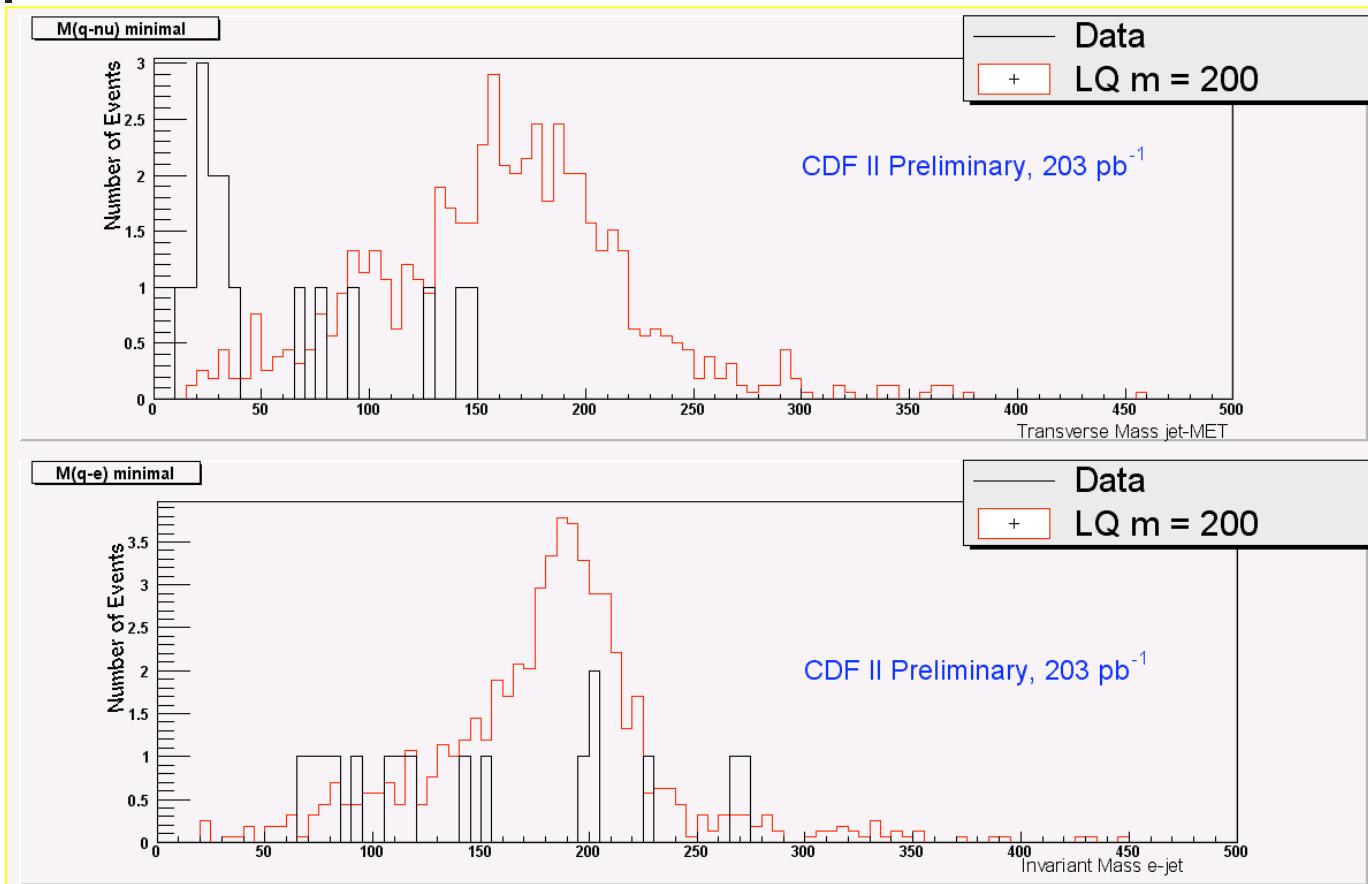


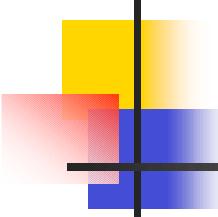
# Results

<b>events with 1 ele &gt; 25 &amp;&amp; MET &gt; 60</b>	<b>1073</b>
<b>events with 1 ele, MET and &gt;= 2 jets ( 30 30 )</b>	<b>125</b>
<b>events with 1 ele, MET and &gt;= 2 jets and dphi cut</b>	<b>104</b>
<b>events with 1 ele, MET and &gt;= 2 jets and dphi cut and 2jet_80</b>	<b>95</b>
<b>events with 1 ele, MET and &gt;= 2 jets and dphi cut and 2jet_80 and T mass cut</b>	<b>18</b>

<b>Mass</b>	<b>100</b>	<b>120</b>	<b>140</b>	<b>160</b>	<b>180</b>	<b>200</b>	<b>220</b>	<b>240</b>	<b>260</b>	<b>280</b>
W+2 jets	1.5±0.9	1.5±0.9	1.5±0.9	2.5±1.13	2.5±1.13	2.5±1.13	2.0±1.0	2.0±1.0	1.5±0.8	0.5±0.4
top	2.5 ±0.6	3.08 ±0.6	2.9 ±0.6	2.6 ±0.6	2.3 ±0.5	1.8 ±0.5	1.5 ±0.3	1.0 ±0.3	0.7 ±0.2	0.6 ±0.2
Z+jets	0.05 ±0.01	0.05±0.01	0.08±0.02	0.08±0.02	0.08±0.02	0.08±0.02	0.06±0.02	0.06±0.02	0.04±0.01	0.04±0.01
Total Data	4.2±3.8	4.65 ±4.3	4.5 ±4.0	5.16 ±4.3	4.85 ±4.0	4.47 ±3.8	3.6 ±3.2	3.1 ±2.8	2.3 ±2.1	1.1 ±1.1
	<b>7</b>	<b>6</b>	<b>4</b>	<b>4</b>	<b>4</b>	<b>4</b>	<b>2</b>	<b>2</b>	<b>2</b>	<b>1</b>

# Results

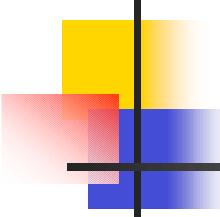




# Systematic uncertainties

---

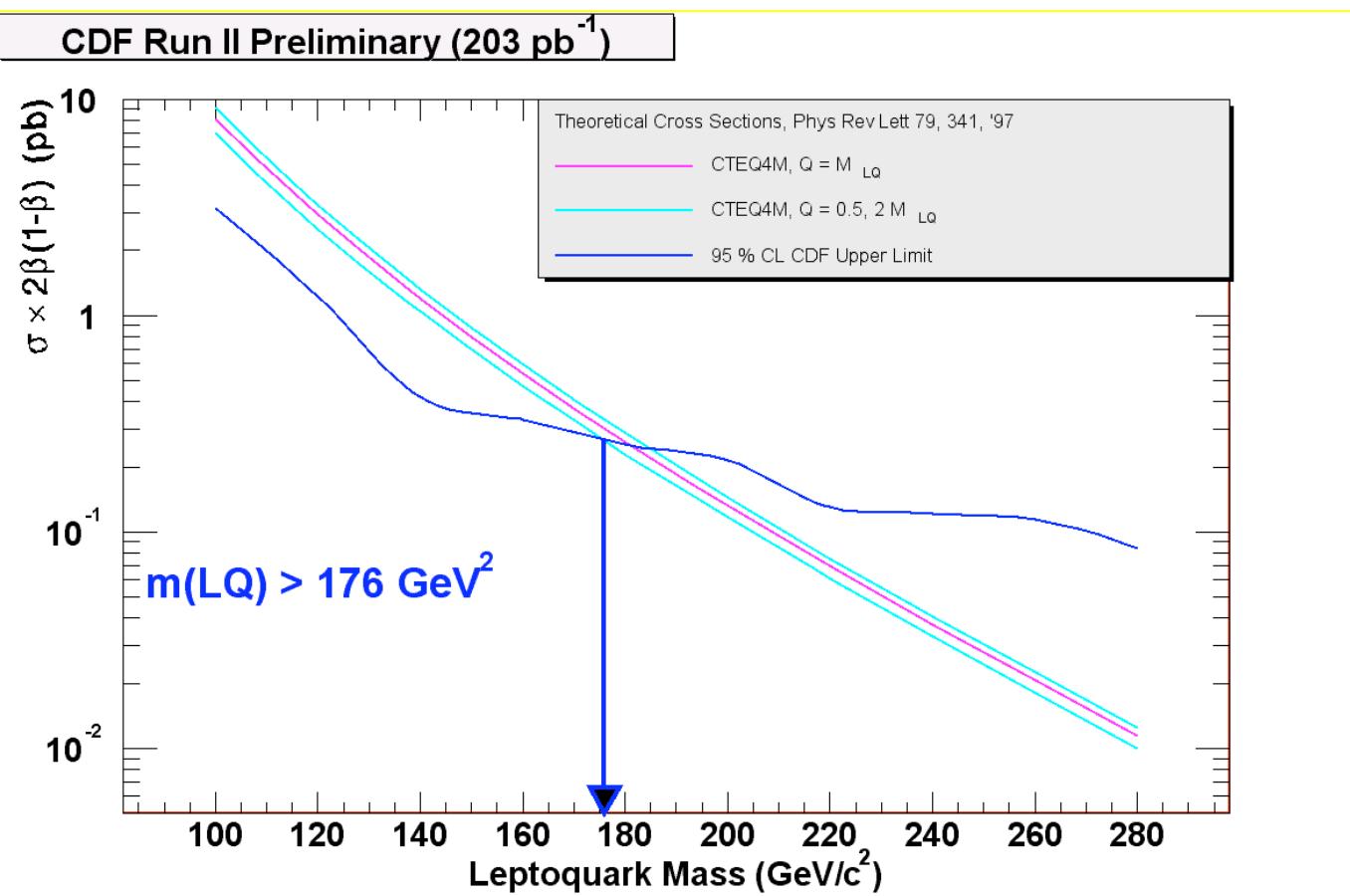
- Luminosity: 6%
- Acceptance
  - pdf 2.1%
  - statistical error of MC 1.4%
  - jet energy scale ( Level 3)
    - jets corrected for energy scale, time dependent and relative response
    - jet energy scaled of systematic uncertainty + 5% ( energy scale + 5% data/MC adjustment); 0.4 to 1.0% from mass 100 to 280) 0.6% at 200 GeV/c<sup>2</sup>
- Event vertex cut : 0.5%
- ISR/FSR - 1.8%

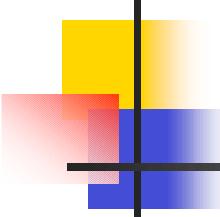


# Final acceptances and errors

Mass	A(LQ)	Stat (Abs)	Sys (Abs)	Total	Relative
100	0.017	0.0019	0.001	0.135	
120	0.038	0.003	0.003	0.104	
140	0.085	0.004	0.006	0.09	
160	0.107	0.005	0.008	0.086	
180	0.139	0.005	0.010	0.082	
200	0.165	0.005	0.012	0.082	
220	0.195	0.006	0.014	0.080	
240	0.210	0.006	0.016	0.080	
260	0.226	0.006	0.168	0.079	
280	0.249	0.006	0.018	0.078	

# Cross section Limit





# Conclusions

---

- A revision of the search for first generation LQ pair decaying into  $e\bar{q}q$  has been performed
  - New data sample - 203 pb-1
  - New final selection cut
  - Revised backgrounds
  - Cross check with  $W$  and  $W + 2$  jets cross section
  - Mass limit for  $\square = 0.5$  176 GeV/c<sup>2</sup>

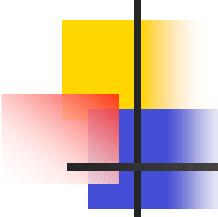
# New MET cut

The Missing Et cut has been raised to 60 GeV

Background reduced by a factor  $\geq 2$  ( top, W + 2 jets)

Signal stays the same

M(LQ)	140	200	280	W+ 2 jets	
$E_T > 35$	$0.08 \pm 0.01$	$0.17 \pm 0.01$	$0.26 \pm 0.006$	1.5	5.5
$E_T > 60$	$0.07 \pm 0.01$	$0.16 \pm 0.01$	$0.25 \pm 0.006$	1.5	9.5
<b>Top</b>					
2.5	3.08	2.9	2.6	2.3	1.8
1.5	1.0	0.7	0.6	2.5	9.9
4.0	5.0	5.2	4.8	4.2	3.6
3.2	2.2	1.6	1.2	2.5	10.5
				2.5	10.
				2.5	9.0
				2.0	8.0
				2.0	7.0
				1.5	5.5
				0.5	3.5

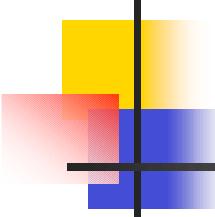


# Other Cuts Efficiency

We studied the effect of 5 cuts on signal ( $m(LQ) = 200 \text{ GeV}/c^2$ ) and  $W + 2 \text{ jets}$  and Top ( main background)

Analysis of the signal and background reduction by applying all but one cut (N-1)

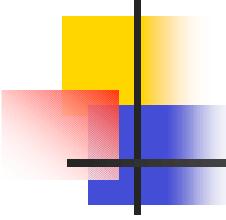
	Signal	$W + 2\text{jets}$	Top
$P_T \text{ ele} > 25$	14.77	16200	113.8
MET $> 60 \text{ GeV}$	6.5	22	7.8
2 jets with $E_T > 30 \text{ GeV}$	7.8	20.5	6.2
$\Delta\phi(\text{MET-jet}) > 10^\circ$	6.2	5	5.3
$E_T(j1) + E_T(j2) > 80 \text{ GeV}$	5.9	3.5	5.0
$M_T(e-\ell) > 120$	7.1	64.5	22.06
After all cuts in sequence	5.8	3.0	4.82



# Acceptances - numbers

Cuts	Cdf 6746	W + 2 jets	$m(LQ) = 200$
Iso < 0.1	$97.2 \pm 0.2$	$95.7 \pm 0.2$	$95.7 \pm 0.2$
Had/EM	$99.0 \pm 0.1$	$99.9 \pm 0.2$	$99.5 \pm 0.2$
E/P	$99.0 \pm 0.1$	$97.29 \pm 0.2$	$96.8 \pm 0.2$
Dx	$98.9 \pm 0.1$	$98.9 \pm 0.2$	$98.4 \pm 0.2$
Dz	$99.7 \pm 0.1$	$99.3 \pm 0.2$	$98.9 \pm 0.2$
lshr	$98.7 \pm 0.1$	$98.6 \pm 0.2$	$98.9 \pm 0.2$
$\square_T$	$94.5 \pm 0.2$	$89.9 \pm 0.2$	$88.1 \pm 0.2$

Efficiency of the ID cuts for central electrons - individual cuts



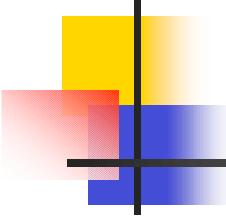
# MetSig Cut Removal

---

The  $E_T$  significance cut is not optimal:  
large systematic associated due to mis-modeling of Sumet in MC  
Sumet is generally smaller in MC  
“overefficiency” in MC : for the same MET, Metsig is smaller in data

Mass Cut is used instead of Missing Et significance

It was used in Run I  
Signal efficiency acceptable ( same as Metsig cut)  
Powerful background constrain, better controlled as function of LQ mass  
**BETTER LIMIT !**



## Mass cut issues (con'td)

We have also checked the mass cut applied in the Run I  $\ell\ell jj$  analysis ( which Dan will use)

- $|M(\mu j_1) - M_{LQ}| < 2\sigma_1$  OR  $|M(\mu j_2) - M_{LQ}| < 2\sigma_2$
- $M^T(\not{E}_T j_1) > T_1^{\min}$  OR  $M^T(\not{E}_T j_2) > T_2^{\min}$

LQ mass region	signal	W+2 jets	Top
$M(LQ) = 160$	11.7 vs	2.0 vs 2.5	2.6 vs 3.2
$M(LQ) = 200$	4.5 vs 4.8	2.5 vs 5.5	1.8 vs 2.4
$M(LQ) = 240$	1.6	2.5 vs 9.0	1.0 vs 1.2